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FYP 2 FINAL REPORT

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PROJECT TITLE

DEVELOPMENT AND TESTING OF INTUMESCENT FIRE RETARDANT COATING ON VARIOUS STRUCTURAL GEOMETRIES

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REV	**DATE**	**DESCRIPTION**	**PREPARED**	**ID**	**CHECKER**	**MARKS**

ABSTRACT

Materials are very prone to catching fire regardless of its type. Once it catches fire, it will take certain amount of time to wipe it off depending on the rate of burning. A small fire will take less time to be cleared where by a big burn out will take a couple of hours to wipe it out. Buildings nowadays can be prone of catching fire and its build on various structural geometries. As it is, Traditional fire retardants are not very effective especially when there is a huge breakout of fires in plants and platforms. These traditional fire retardants also contain halogen and releases toxic vapours thus leading to a severe threat to life and environment. By contrast, intumescent coatings are relatively thin-film products that expand rapidly in a fire to insulate the steel. They come in various formulas that include a mixture of binders and acids that react under temperature to expand up to many times the original thickness of the film, creating a char that insulates the steel. In general, steel loses half its strength at 1,100 °F and begins to degrade as well as starts to loose its properties. Consequently leads us to the aim of this project which is to study the details of the expansion of char and heat shielding performance on various structural geometries with respect to inorganic fillers, (Aluminium Tri-Hydrate) and without filler. Researcher will develop an intumescent coating formulation with inorganic fillers and with no filler in order to get the comparison of optimal performance for char expansion and heat shielding performance on the various structural geometries. In order to meet these challenges, IFRC will be developed and tested on geometries such as T-joints, Elbows, I-Beams and Pipes. The development of coating will consist of three agents mainly Acid Source (APP, Polyphosphate), Carbon Source (EG, Expandable Graphite) and blowing agent (MEL, Melamin) followed by Epoxy, Boric Acid, Polyamide Hardner, etc. Once this coating is mixed, it will then be applied on the various structural geometries. This coating will then be tested in furnace and fire (Bunsen burner). The char expansion as well as heat shielding will be thoroughly observed and results will be obtained and further studied.

CHAPTER 1: INTRODUCTION

1.1 Background of study

The protection of metallic materials against fire has become an important issue in the construction industry. Indeed, prevention of the structural collapse of the building is paramount to ensure the safe evacuation of people from the building, and is a prime requirement of building regulations in many countries [11]. Steel usually begins to lose its structural properties above 500°C. Intumescent coatings are designed to perform under severe conditions and to maintain the steel integrity for between 1 and 3 h in some cases when the temperature of the surroundings is in excess of 1100 °C.[13-15] Upon heating, foamed cellular charred layers are formed on the surface, which protect the underlying material from the action of the heat and/or flame.

Intumescent thick films are usually based on epoxy, vinyl, or other elastomeric resins and contain ingredients providing intumescence upon heating [10]. They are available as solvent-free systems, permitting the application of up to 8-10 mm thick coating. They are hard and durable, and some of them can provide excellent protection from corrosion [12]. They exhibit very high adhesion to the substrate and resistance to impact, abrasion, and vibration damage. High tensile and compressive strengths can be obtained, and weather resistance is excellent.

These intumescent coatings are high-value products for industries, and the competition in developing new products is high. But the development of new intumescent coatings depends on many parameters: the Intumescence concept requires a balance between the fire properties and the level of additives in the material. The formulation of the coating has first to be optimized in terms of physical and chemical properties (char strength, expansion, and viscosity, etc.) in order to form an effective protective char. This latter should limit both the heat transfer from the heat source to the substrate and the mass transfer from the substrate to the heat source, resulting in conservation of the underlying material.

1.2 Problem statement

Fire accidents takes long hours of time to wipe them out depending on the material type and where its placed at that particular time. With that, fire accidents have been constant threats to human's health as well as materials. Traditional flame retardants are not very effective, when it comes to huge flames break out in either in a plant or platforms or etc. This huge flame when it breaks out has halogen containment and also releases toxics vapors bringing harm to leavings in surroundings area. During polymer combustions, there will be an additive which increases the amount of charcoal-like or carbon-acceous gas.

1.2.1 Problem Identification

Different structural geometries with inorganic filler and without will react differently onto Intumescent coating which its result reflects on the expansion of char and heat shielding performance differences.

1.2.2 Significant of Project

The main aim of this project is to observed the char expansion and the ability of heat shielding performance on various structural geometries such as T-Joints, I-Beams, Elbow and Pipes with respect of compairison between inorganic filler (ATH, Aluminium Tri-Hydrate) and without filler.

The reason why the test will be carried out with one coating having filler and the other without is to have comparison of results and observe the behavior and diffrence between this two on the various structural geometries.

1.3 Objective

To develop an intumescent coating formulation and study on the details of the expansion of char and heat shielding performance on different structure geometries (T joints, Elbows, Pipes and I-Beams).

1.4 Scope of Study

The main focus of studies will be on the expansion of char that is influenced by inorganic fillers. Firstly, the provided formula will determine in the making of the intumescent coating. Melamine, APP, Epoxy (bisphenol A), Boric Acid, ACR Polyamide Hardener, are some of the substance needed in developing the coating. Inorganic fillers are also added as part of the mixture for the development of Intumescent coating.The completed coating will than be applied onto various structure geometries (T-joint, elbows, pipes and etc) and left to dry. The expansion of will be observed after the substrate is exposed to heat from a Bunsen burner. Improvisation on the formula is recorded down and will be further studied in the future for improvisation.

1.4.1 Relevancy of the Study

This project discusses on the effects of Inorganic fillers and without onto the performance of Intumescent coating based on various structural geometries. The project as per stated has its relevancy to the course that the author is undertaking, Mechanical Engineering. Under this course there are a few subjects that will help contribute information as well as better understanding to help make this project a successful one. The subjects are :-

1) *Engineering Materials*
2) *Manufacturing Technology*

1.4.2 Feasibility of the Project within the Scope and Time Frame

There are three divition in this project. First part will consist of finding, collecting, and reading of journals, technical papers, and books of the research topic. Understanding about the coating shall all be done in this section.

Developing oof the intumescent coating with formulation will be done in the second sector. The formulation of intumescent coating consist of :-

- Expandable Graphite
- Melamine
- Ammonium Polyphospate
- Epoxy Resin Bisphenol A
- Triethlyene-Tetramine
- Fumed Silica and Aluminium Tri-Hydrate
- Graphite
- Sulphuric Acid
- Boric Acid
- Acetic Acid

Frnance test and Bunsen burner test will be carried as the third section. This experimental test are carried out to monitor the expansion of char as well as the heat shielding effects.

Final section will be analytically observing the results obtained from experiments and further documenting the data to show findings. Data and findings are formally presented in written format as well as presentation slides with the help of visual and graphical aids.

CHAPTER 2: LITERATURE REVIEW

Intumescent Coating

The word “intumescent” comes from a latin word means “to swell up [1].The protection of materials against fire has become an important issue in the construction industry. Using flame retardant coating is one of the most efficient and convenient way to protect materials such as metals, polymers, textiles and woods against fire [2]. It presents two main advantages: it can prevent heat from penetrating and flames from spreading. Moreover it does not modify the intrinsic properties of the materials (e.g. the mechanical properties)[3]. The starting formulation of every intumescent paint included thermally inert feldspath fillers and intumescent components (melamine, pentaerythritol, ammonium polyphosphate), binders (solvent-borne acrylic copolymers, epoxy/polyamide curing systems and water-borne dispersions of vinyl copolymers) and additives (defoamers, wetting and dispersing agents) [4].

In general, flame retardant coatings can be classified into two groups: non-intumescent coating and intumescent coating. Intumescent flame retardant coatings are made up of intumescent flame retardant (IFR) system, binder and fillers. The intumescent flame retardant system usually composed of three active ingredients: an acid source (generally ammonium polyphosphate-APP), a carbon source (such as pentaerythritol-PER) and a blowing agent (most often melamine-MEL). Upon heating, the three active ingredients and the binder swell and form a thermal insulation multicultural layer[2]. Intumescent coating is inert at room temperature but intumesces up to 100 times its initial thickness when exposed to heat, forming a cellular charred layer of low conductivity foam. The foam layer protects the substrate steel from a fire, reduces the rate of temperature rise in the steel, and prolongs its load bearing capacity [5].

Intumescent on Steel

Structural steel is widely used in modern structural construction all over the world. It is an important and prime requirement of building regulations for steel-framed buildings to have sufficient fire resistance and one way to achieve this requirement is to apply passive fire protection to the structural steel [5]. Intumescent flame-retardant coating is typically demonstrated in fire testing to determine the ability to maintain structural steel elements at temperatures below critical temperature of 550 °C. Usage of intumescent coating is highly recommended as passive fire protection in building construction as it could save precious human lives and assets [6]. The practice of protecting structural steel members in buildings with intumescent coatings is now well established. In the event of a fire, the coatings are designed to expand on contact with heat to provide a thermally insulating char that delays diffusion of heat to the steel [7].

Intumescent coatings are composed of three flame-retardant additives: an acid source (such as ammonium polyphosphate and APP), a carbon source (such as pentaerythritol and PER), and a blowing agent (such as melamine and MEL). The coatings form an intumescence char layer when exposed to heat, which acts as a thermal barrier that effectively protects the substrate against fire, thereby maintaining the structural integrity of the building. Following recent experimental work, several researchers have extensively studied the physical–chemical mechanisms, flammability and characterization of the intumescent coatings properties. The fire protection provided by intumescent coatings occurs by three reaction processes: (i) the coating material decomposes, (ii) inert gases evolved from the decomposition reaction are produced at a rate high enough to drive back hot convective air currents, and (iii) the coating expands into a highly porous char layer with a high resistance to heat conduction from the flame into the underlying steel substrate [6].

The process of intumescence is complex and despite the fact that it has been exploited in commercial coatings, remains poorly understood. It involves an interplay of physical and chemical processes that must occur in correct sequence in order to produce the insulating char. Furthermore, since the char must be highly porous to provide thermal insulation, the average wall thickness of the solid matrix must necessarily be low. This in turn presents difficulties in maintaining sufficient strength so that the char remains in place during a fire.[7]

Intumescent on Joints

Joints are critical members in steel-framed structures. In particular, how joints behave in steel-framed structure has a critical influence in controlling progressive collapse of the structure under accidental fire attack. Despite extensive previous research on steel-framed structures in fire, which has resulted in the development of fire engineering design methods that are now being routinely adopted in steel structural design, large gaps still exist in the understanding of joint behaviour in fire. Following the World Trade Center disaster, a number of authoritative organizations have identified joint integrity as key to maintaining structural integrity in a fire and have called for extensive research on joints under fire conditions [8].

The current practice to ensure that joints have sufficient fire resistance is simple: to protect joints to the highest level of fire protection based on the connected members. This is based on the assumption that because joint components have lower section factors compared to the connecting members (defined as the ratio of the fire-exposed surface area to the volume of steel being heated) the temperature rise in the joint components is lower than in the connected members. One immediate shortcoming of this approach is that some joint components may be subject to higher levels of loading than the connected members. More importantly, under fire conditions, the behavior of a steel structure is complex with forces in different members changing during the entire course of fire exposure. These forces are transmitted from one connected member to another, mainly dependent on the behavior and performance of the joints, making understanding joint behaviors in fire a key factor in structural fire design [8].

Steel being a thermally high conductive material, the temperature rise in unprotected steel exposed to fire attack is quick, resulting in rapid loss in strength and stiffness of steel in fire. To ensure sufficient fire resistance of steel-framed structures, fire protection is often required to limit temperature rises in steel. Currently, intumescent coating is the most popular type of fire protection, representing about 50% of the passive fire-protection market in the UK. [8]

Intumescent Epoxy resin

Intumescent epoxy resins are a ‘mix of thermally reactive chemicals in a specific epoxy matrix formulated for fireproofing applications’. The main characteristic of such materials is to present a pre-set thermal decomposition behavior: under fire conditions, the thermal degradation reactions on one side emit significant amounts of gases and, on the other side, form a highly-porous carbonaceous char. Both the phenomena contribute to enhance the thermal insulation properties of the material, generating a low-density porous structure which provides an effective barrier to heat transfer.

As such, intumescent epoxy resins are used for fireproofing purposes. First applications date back to the ‘80s, especially for military purposes (fire protection of ordnance). Presently, intumescent epoxy resins are employed in a wide spectrum of fireproofing applications, that include protection of structural steel elements in civil constructions as well as of pipe work and equipment in process plants [9]. Thin film intumescent coatings have become the dominant choice for passive fire protective materials because of their many advantages including: flexibility and ease of usage for both on- and off-site applications, light-weight, thin and attractive appearance, and high standard finish.

CHAPTER 3: METHODOLOGY

3.1 Project Work

To come up with the project methodology, first of all there need to be lots of reading and research done on various journels and article to get an understanding of the project topic. After that the objective is worked in place. The outcome is to meet the project objective in FYP 2 which will be based on experiments.

Below is a brief approach taken by the author in planning a successful project and aims for success.

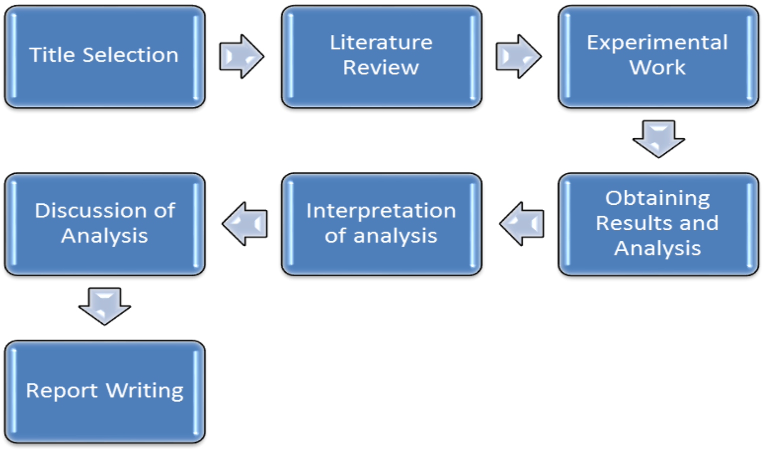


Figure 1 : Project Activities Flow Chart

Title Selection - Final year project title selection / proposal

Literature Review - Learning of previous research work and concept

Experimental Work -Learning how to use the equipments and to conduct experiment appropriately to the study.

Results Analysis -Measure the expansion of char on various as well as analyze the heat shielding based on various structural geometries.

Interpretation of study -Interpret the findings into a tabular form. What are the differences Analysis in the expansion of char on various structural geometries?

Discussion - Discuss the findings or outcome of the project work and Make suitable conclusion.

Report Writing - Documentation and compilation of the things related to the project (Findings, experimental work, literature review, research outcome)

3.2 Project Activities

Firstly, an Intumescent coating will be developed using a formulation that includes necessary additives. Just after the coating is produced it is coated/applied onto steel structural geometries such as Elbows, T-Joints, I-Beams, and Pipes. These coated substrates are left to cure naturally for several days under room temperature to ensure that it is properly dried. Substrates are experimented with Bunsen burner flame to see he heat shielding effect and char expansion. Result obtained from experiment is thoroughly viewed and studied with the help of microscopic aids and software.

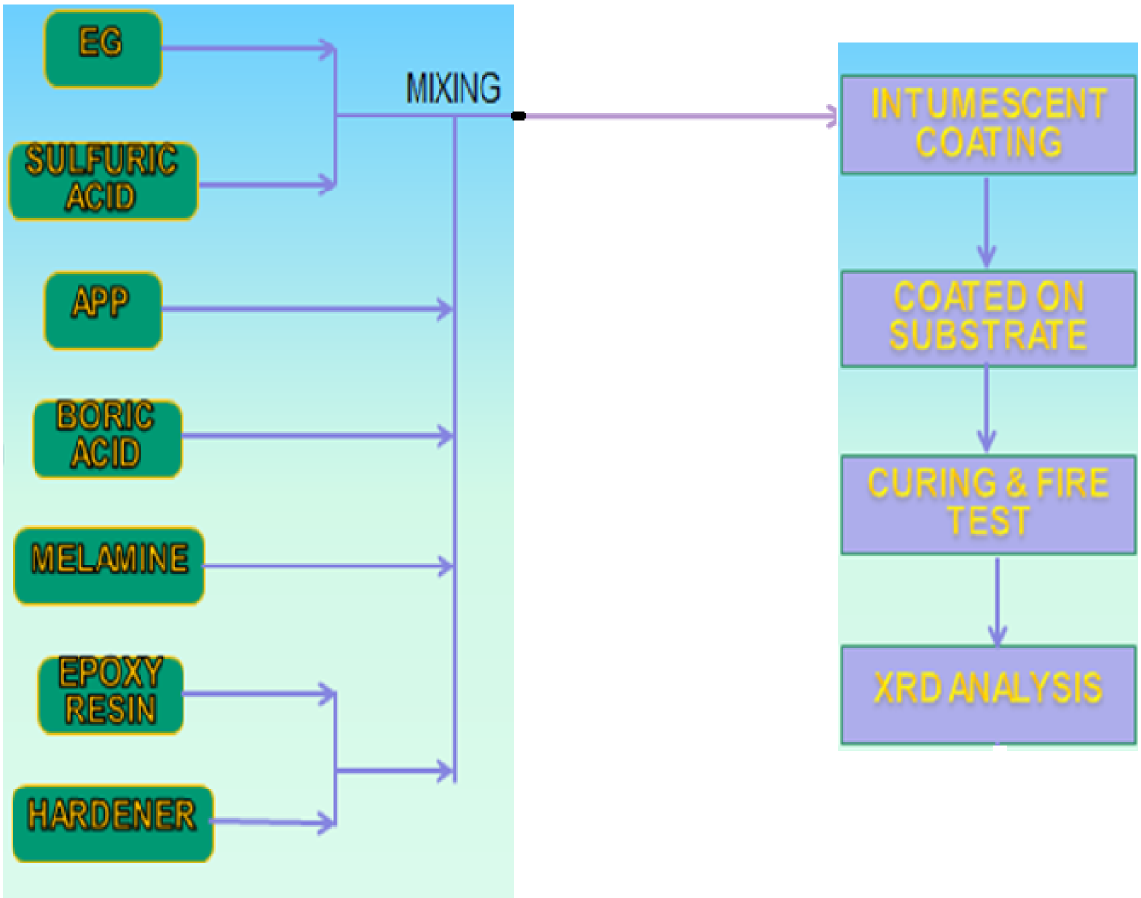


Figure 2: Mixing of Coating and Test Required

NO	*SAMPLE*	*BPA (g)*	*TETA (g)*	*APP (g)*	*EG (g)*	*MEL (g)*	*BA (g)*	*FILLER (g)*
0	**NO FILLER**	44.44	22.22	11.11	5.56	5.56	11.11	0
1	**ATH 1**	43.94	21.72	11.11	5.56	5.56	11.11	1
2	**ATH 2**	43.44	21.22	11.11	5.56	5.56	11.11	2
3	**ATH 3**	42.94	20.72	11.11	5.56	5.56	11.11	3
4	**ATH 4**	42.44	20.22	11.11	5.56	5.56	11.11	4
5	**ATH 5**	41.94	19.72	11.11	5.56	5.56	11.11	5

ATH	**ALUMINIUM TRI-HYDRATA**

Table 1: Intumescent coating formulation of mixture

3.2.1 Intumescent Coating procedure of preparation

1. The materials in the table above are weighed using weighing scale.
2. A grinder is used to grind each sample prepared
3. Epoxy (BPA) and Hardener (TETA) is mixed in a different container according to the listed weight once the samples are grinder properly.
4. Using mixer for approximately 10 minutes, mix the Epoxy and Hardner together.
5. With the speed of 60Rpm, add the grinded mixture of sample into the mixed epoxy and hardener slowly using a mixer.
6. In order to ensure a proper mixing coating, substrate is left mixing for about good 20-30 minutes.
7. Completed mixture is coated on the structural geometries (Elbows, T-Joints, I-Beams, and Pipes) and left for curing naturally under room temperature for approximately one day.

3.2.2 Task Completed (FYP 1)

- Identification of Title and Project Objective
- Research Works
- Methodology
- Preparation of sample for Inorganic filler (Aluminium Tri- Hydrate) and without filler.
- Grinded mixed and coated sample (0 and 5 for ATH) onto the structural geometries and left for drying naturally under room temperature.

3.2.3 Task Completed (FYP 2)

- Completed grinding, mixing, and coating the samples onto the structural geomerties.
- Completed furnace test at 450 degree Celsius for ATH 0 and 5 percent.
- Recorded results of heat shielding test for all substrates.
- XRD testing are sent for selected substrate.
- TGA testing are sent for selected substrate.
- Char expansion for furnace test are measured.
- Results obtained are discussed.

3.2.4 Tools Required

- Furnace
- Grinder
- Bunsen burner
- Thermologger (Temperature Gauge)
- Thermo gravimetric analysis (TGA) - thermal stability of coating.
- X-Ray Diffraction (XRD) - charring layer and their morphological structures.

3.3 Gantt Chart and Key Milestone

No	Detail / Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic															
2	Preliminary research work															
3	Submission of Extended Proposal															
4	Proposal Defense								Mid Semester Break							
5	Experimental works, familiarize with the equipments															
6	Experimental works regarding with materials (preliminary)															
7	Submission of Interim Draft Report															
8	Submission of Interim Report															

Figure 3: Gantt chart for the first semester project implementation

Processes

Milestones

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Results

4.1.1 Measurement for IFR coating with (ATH 5%)/without filler for T-joint, I-Beam, Elbow and Pipe.

Thickness of the coating coating on the geometries are measured at four points using a caliper and the average value is taken. Once the sample undergo furnance test, the char expansion is measured using a ruller. Measurements of char expansion are also taken at four points with its most peak and three other points are all taken into an average values in the end. Below are the measurement techniques for T-joint, I-Beam, Elbow and Pipe.

Measurement Technique:-

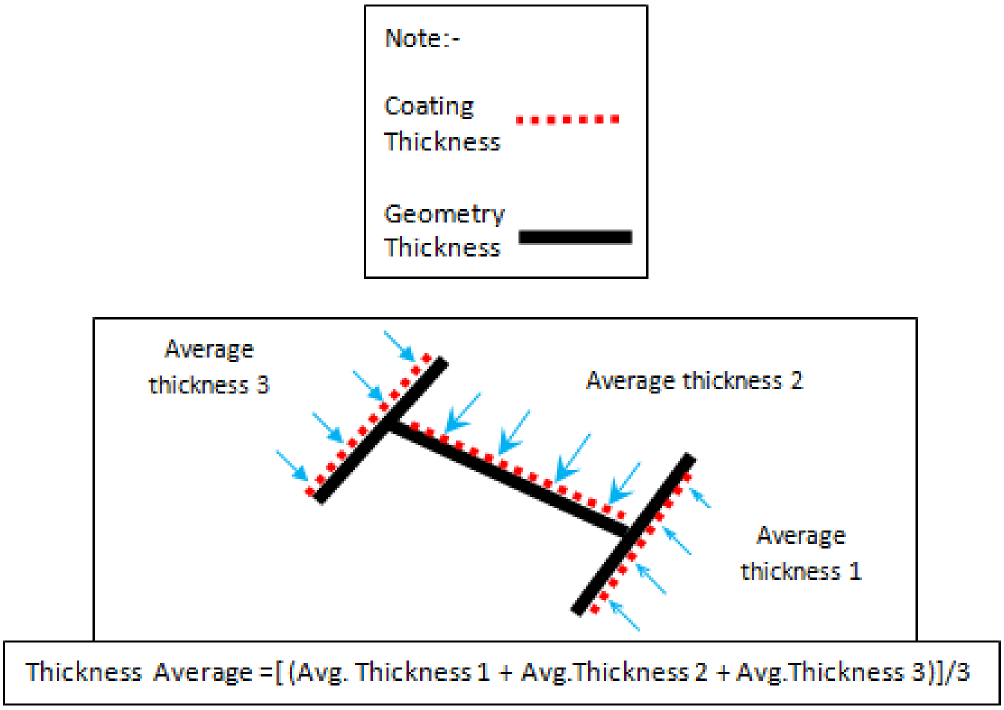


Figure 4: Thickness measurement for I-Beam

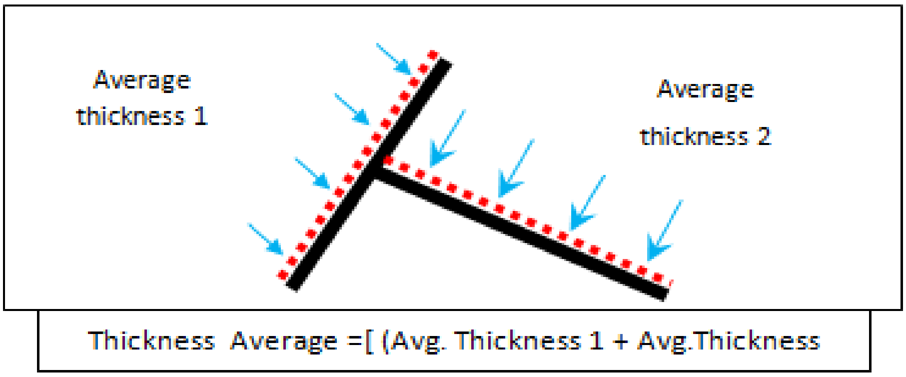


Figure 5: Thickness measurement for T-Joint

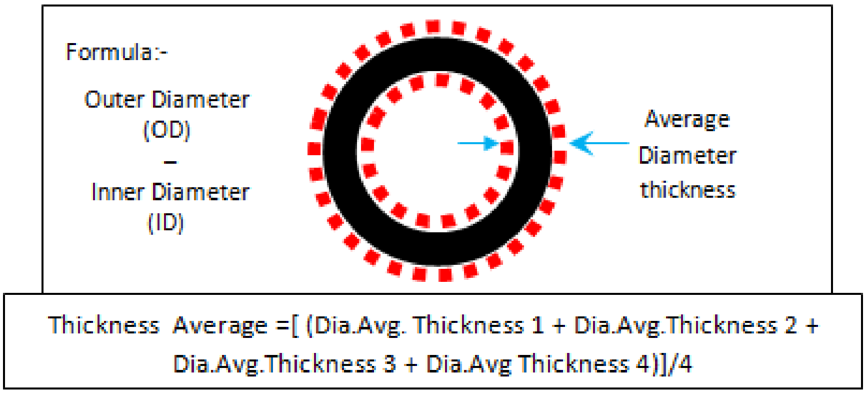


Figure 6: Thickness measurement for Pipe and Elbow

4.1.2 Char Expansion measurement for IFR coating with (ATH 5%) / without filler On T- joint, I-Beam, Elbow and Pipe.

Thickness of the char expansion on the geometries are measured at four points (from highest of peak to the lowest) using a ruller and the average value is taken. Below are the measurement techniques for T-joint, I-Beam, Elbow and Pipe.

Measurement Technique:-

Figure 7 : Char Expansion Measurement Method for I-Beam, T-Joints, Pipes and Elbows

4.2 Experiment Results

4.2.1 Furnace Test Results for ATH 5 % and No filler (NF) Substrate

TEMPERATURE	SAMPLE	NOTE	PICTURE
450 CELCIUS (ATH 5%)	T-Joint	Not Detachable	
	I-Beam	Not Detachable	
	Elbow	Detachable	
	Pipe	Detachable	

Figure 8 : ATH 5% Char Expansion at 450 Degree Celsius

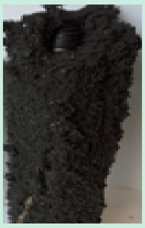
TEMPERATURE	SAMPLE	NOTE	PICTURE
450 CELCIUS (NO FILLER)	T-Joint	Slight Detach	
	I-Beam	Slight Detach	
	Elbow	Detachable	
	Pipe	Detachable	

Figure 9 : NF Char Expansion at 450 Degree Celsius

4.2.2 Furnace tests data for ATH 5% and No Filler (NF) Substrate

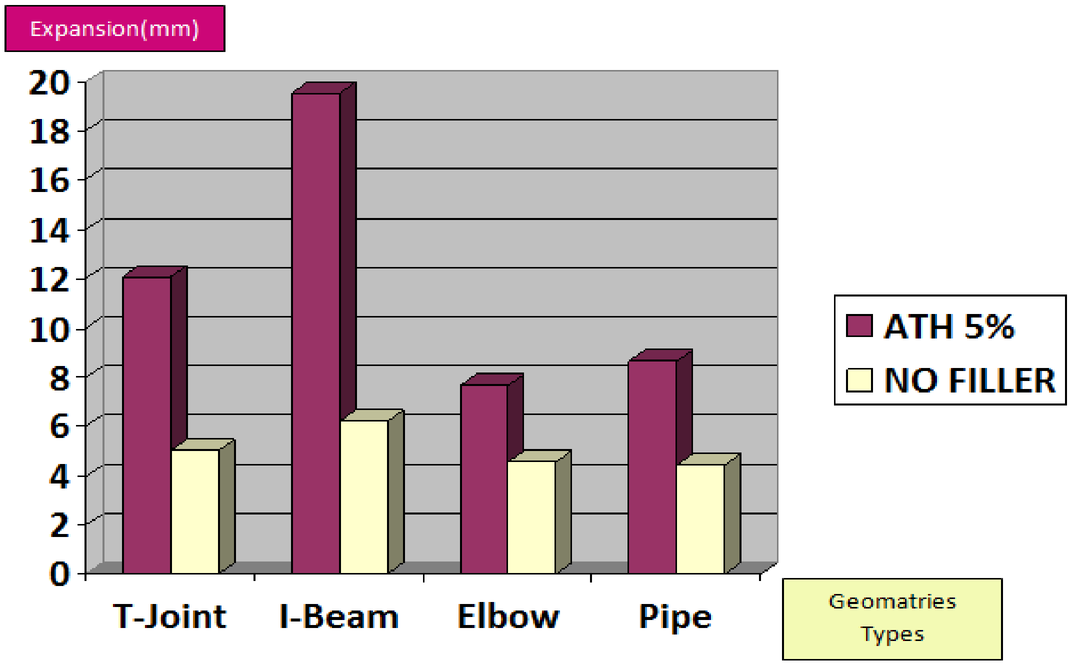
TEMPERATURE	SAMPLE	THICKNESS		EXPANSION
		BEFORE (Coating Thickness)	AFTER (Char Expansion)	
450 CELCIUS (ATH 5%)	T-Joint	0.965	11.65	12.1
	I-Beam	0.99	19.32	19.5
	Elbow	0.98	7.5	7.65
	Pipe	0.98	8.5	8.67

Table 2 : Char expansion of ATH 5% substrates exposed to 450 degree Celsius

TEMPERATURE	SAMPLE	THICKNESS		EXPANSION
		BEFORE (Coating Thickness)	AFTER (Char Expansion)	
450 CELCIUS (NO FILLER)	T-Joint	1.29	6.5	5.04
	I-Beam	0.92	5.7	6.2
	Elbow	1.71	7.8	4.56
	Pipe	1.4	6.2	4.43

Table 3 : Char expansion of NF substrates exposed to 450 degree Celsius

4.2.3 Graphical View of Furnace Tests Result for ATH 5% and NF

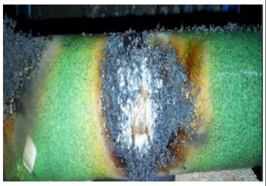


Graph 1 : Graph on Expansion vs Geometri Types for Ath 5% and NF

4.2.4 Heat Shielding Results for ATH 5% and NF Substrate

Sample	Time (Min)	Temp 1 (Degree celcius)	Temp 2 (Degree celcius)	Temp 3 (Degree celcius)	Temp 4 (Degree celcius)	Picture	Note
T-Joint ATH 5%	10	808	39.15	118.7	50.8		NOT DETACHABLE
	20	735	38.15	127.35	52.85		
	30	801.5	37.85	139.2	52.9		
	40	802	46.3	148.75	57.7		
	50	770.5	41.55	132.8	56.45		
	60	853.5	42	146.05	57.15		

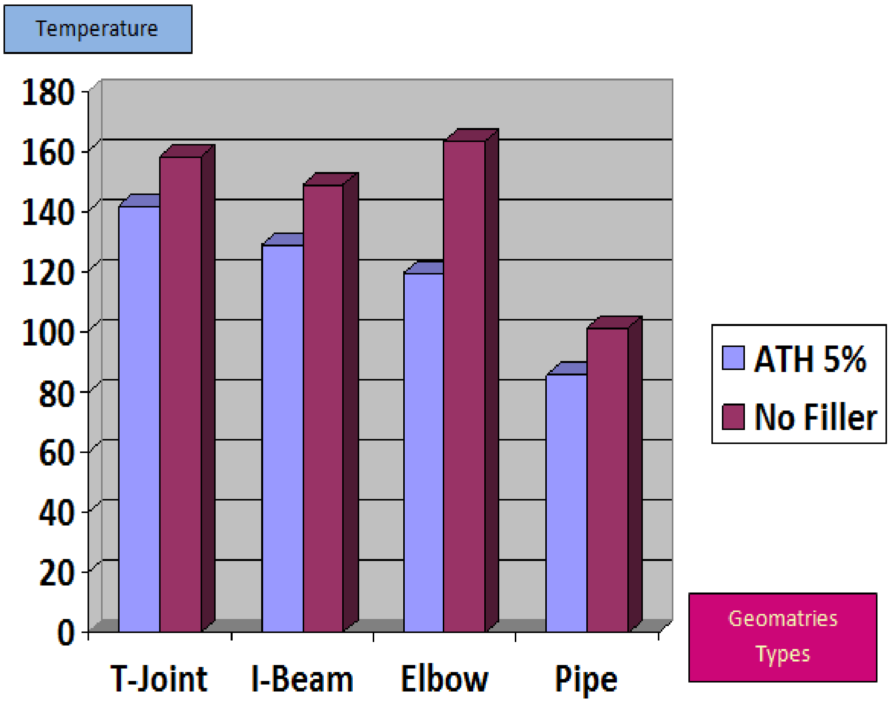
Sample	Time	Temp 1	Temp 2	Temp 3	Temp 4	Picture	Note
I-Beam ATH 5%	10	821.33	77.4	138.1	86.93		NOT DETACHABLE
	20	850.67	90.37	154.57	97.87		
	30	862	84.27	146.7	97.47		
	40	868.67	92.87	165.77	103.9		
	50	865	86.87	159.57	103.03		
	60	900	85.7	157.23	102.23		
Sample	Time (Min)	Temp 1 (Degree celcius)	Temp 2 (Degree celcius)	Temp 3 (Degree celcius)	Temp 4 (Degree celcius)	Picture	Note
Pipe ATH 5%	10	853	97.2	161.2	104.8		SLIGHT DETACHABLE
	20	819	114.1	175.7	119.3		
	30	761	121.2	159.6	119.1		
	40	753	123.3	185.6	125.8		
	50	756	132	201.7	139.9		
	60	781	134.1	138.5	138.5		
Sample	Time (Min)	Temp 1 (Degree celcius)	Temp 2 (Degree celcius)	Temp 3 (Degree celcius)	Temp 4 (Degree celcius)	Picture	Note
Elbow ATH 5%	10	892	68	111.9	76		SLIGHT DETACHABLE
	20	824	79.9	101.2	77.4		
	30	813	84.3	107.4	80.2		
	40	982	94.6	123.7	90		
	50	955	96.6	146.7	108.7		
	60	863	93.4	126	97.3		

Sample	Time (Min)	Temp 1 (Degree celcius)	Temp 2 (Degree celcius)	Temp 3 (Degree celcius)	Temp 4 (Degree celcius)	Picture	Note
T-Joint **NF**	10	706.5	57.9	126.55	78.3		MILD DETACH
	20	708	73.85	141.7	85.4		
	30	728	74.45	149.55	91.35		
	40	803.5	69.55	152.55	91.05		
	50	732	73	158.2	92.2		
	60	766	68.95	159.4	93.7		
Sample	**Time (Min)**	**Temp 1 (Degree celcius)**	**Temp 2 (Degree celcius)**	**Temp 3 (Degree celcius)**	**Temp 4 (Degree celcius)**	**Picture**	**Note**
I-Beam **NF**	10	803.67	71.67	127.23	107.57		MILD DETACH
	20	789.33	83.23	144.47	110.47		
	30	760.3	82.77	148.63	108.1		
	40	806.33	82.67	154.5	116.77		
	50	809	93.47	173.77	121.83		
	60	857.33	96.4	168.73	126.3		
Sample	**Time (Min)**	**Temp 1 (Degree celcius)**	**Temp 2 (Degree celcius)**	**Temp 3 (Degree celcius)**	**Temp 4 (Degree celcius)**	**Picture**	**Note**
Pipe **NF**	10	736	55.4	85.8	58.3		DETACHABLE
	20	734	57.8	92.6	63.7		
	30	785	59.6	93.4	64.6		
	40	938	65.5	107.9	66.8		
	50	986	68.1	111.1	75.5		
	60	807	67.3	111.6	76.3		

Sample	Time (Min)	Temp 1 (Degree celcius)	Temp 2 (Degree celcius)	Temp 3 (Degree celcius)	Temp 4 (Degree celcius)	Picture	Note
Elbow **NF**	10	890	118.7	150.7	126.9		DETACHABLE
	20	852	130.4	157.4	136.4		
	30	804	132.9	162	138.3		
	40	841	143.6	177.4	150.0		
	50	882	141.8	177.6	147.1		
	60	843	133.1	162.2	133.7		

Table 4 : Heat Shielding Results for ATH 5% and NF substrate

4.2.5 Graphical View of Fire (Heat Shielding) Tests Result for ATH 5% and NF



Graph 2 : Graph on Geometri Types Vs Temperature for ATH 5% and NF Substrate

4.2.6 Summary of Heat Shielding Effect Data

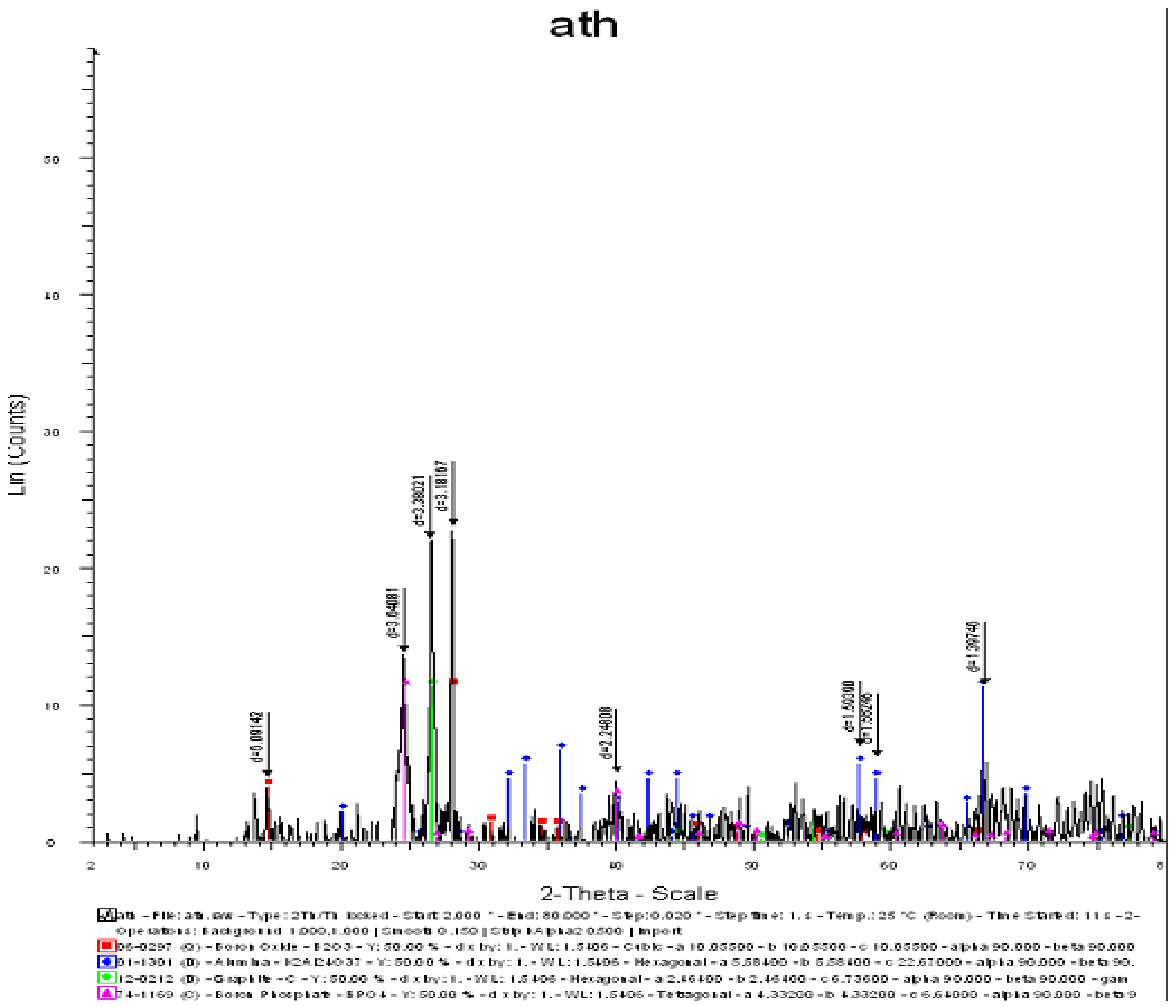
HEAT SHIELDING (ATH 5%)	SAMPLE	THICKNESS		EXPANSION	FINAL TEMPERATURE
		BEFORE	AFTER		
	T-Joint	0.965	11.65	12.1	142.02'C
	I-Beam	0.99	19.32	19.5	128.93'C
	Elbow	0.98	7.5	7.65	119.48'C
	Pipe	0.98	8.5	8.67	85.75'C

Table 5 : Heat Shielding Effect Data for ATH 5%

HEAT SHIELDING (NF)	SAMPLE	THICKNESS		EXPANSION	FINAL TEMPERATURE
		BEFORE	AFTER		
	T-Joint	1.29	6.5	5.04	158.12'C
	I-Beam	0.92	5.7	6.2	165.58'C
	Elbow	1.71	7.8	4.56	164.55'C
	Pipe	1.4	6.2	4.43	100.4'C

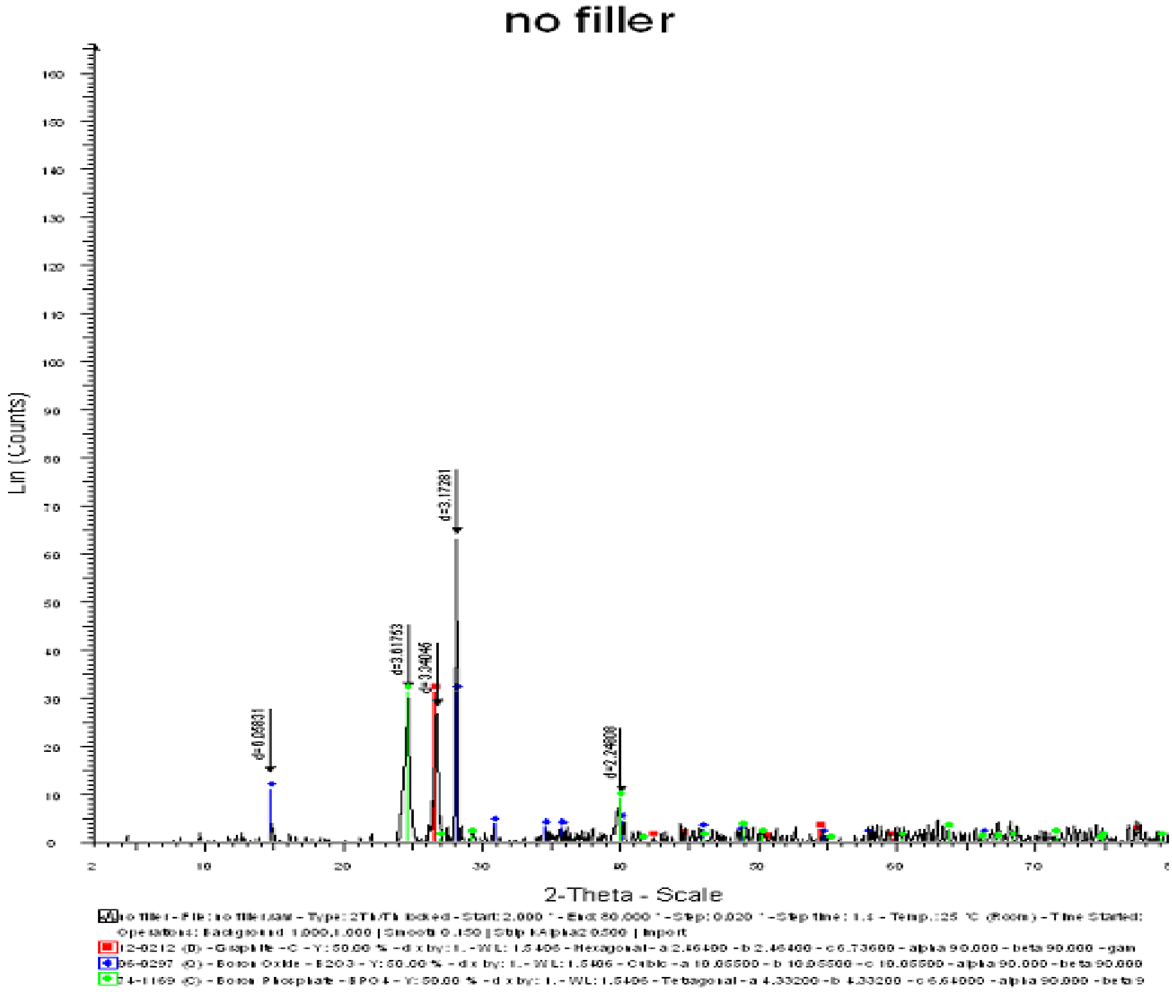
Table 6 : Heat Shielding Effect Data for NF

4.2.7 XRD Results for ATH and NF Substrate at 450'C



Graph 3 : XRD result ATH 5% at 450 Degree Celsius

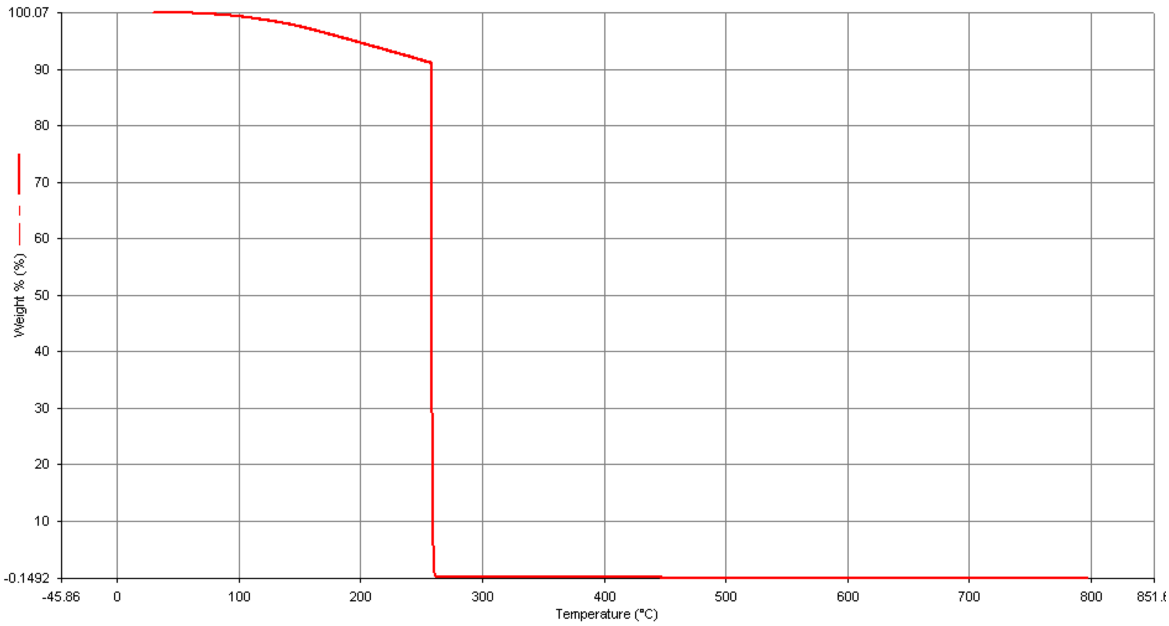
The xrd results sbove states that even tho after heating up in the furnance at 450 degree celsius, there are still the existance of particles such as Boron Oxide, Boron Phosphate, Graphite and Alumina. This indicates that the formulation mixed has the tendency to widhstand high temperature. The graph above shows that the reaction between the formulation mixed is proven to widhstand high temperature hence making intumescent coating a success.

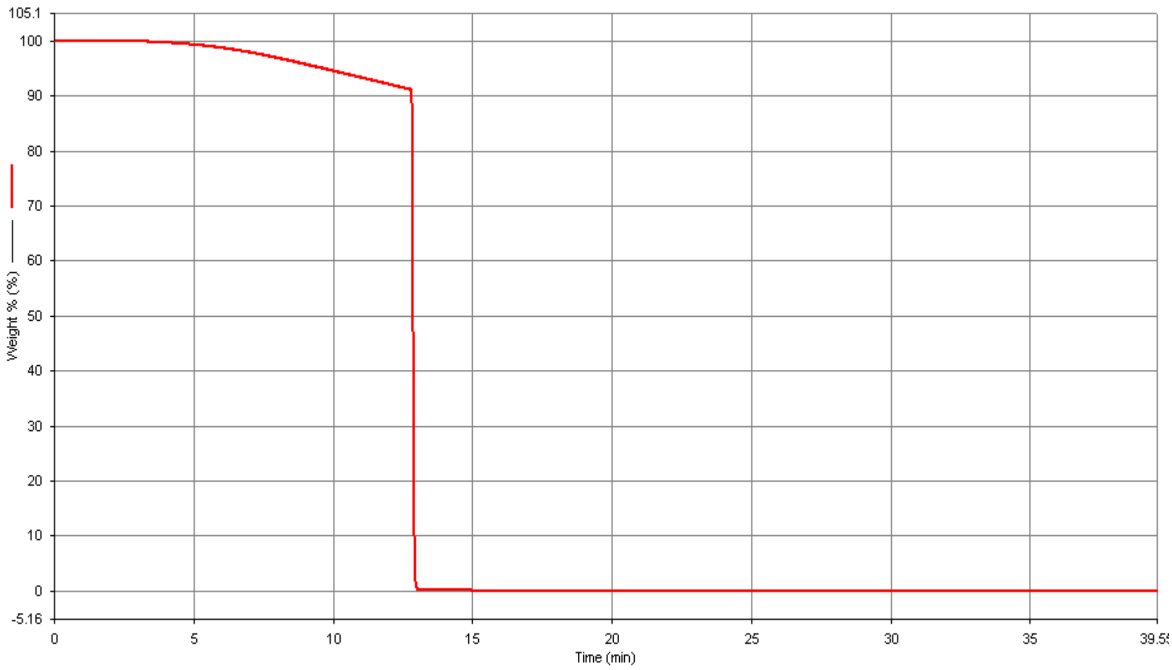


Graph 4 : XRD result NF at 450 Degree Celsius

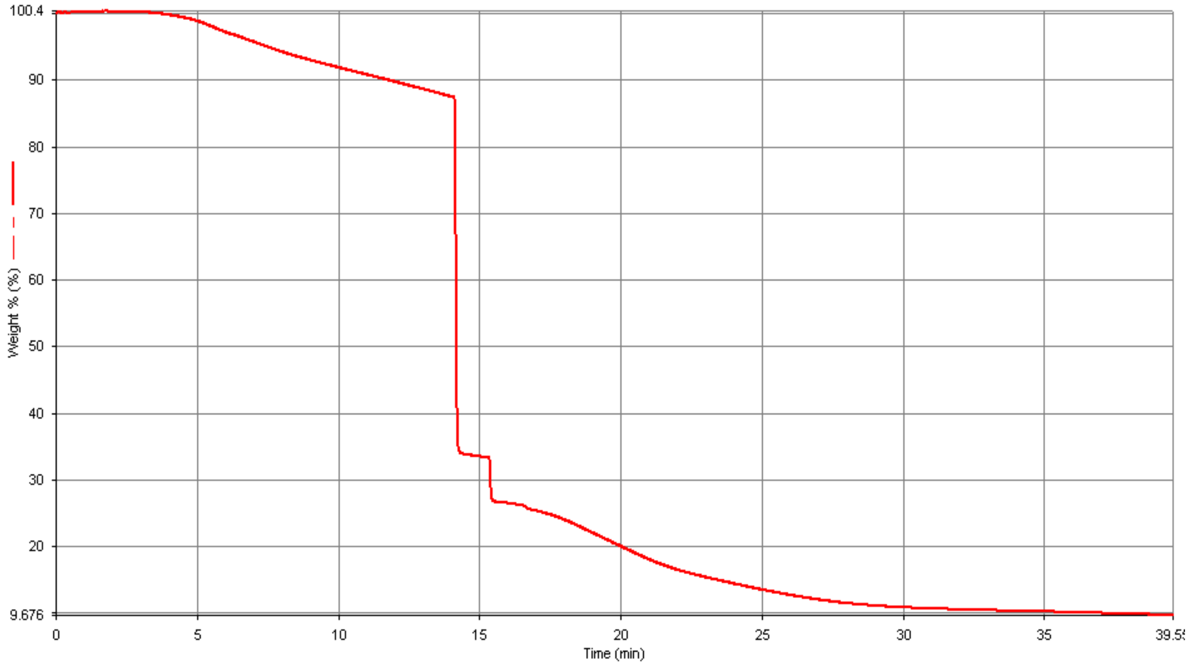
The xrd results sbove states that even tho after heating up in the furnance at 450 degree celsius, there are still the existance of particles such as Boron Oxide, Boron Phosphate, and Graphite. This indicates that the formulation mixed has the tendency to widhstand high temperature. But the non existance of Alumina proved to be crucial in the char expansion results which ATH5% has the best expansion as per the results obtained above. This shows that the existance of filler gives more strenght for intumescent to widthstand higt temperature. With this, its proven that the existance of alumina caust ATH 5% to expend more compared to the coating with NF.

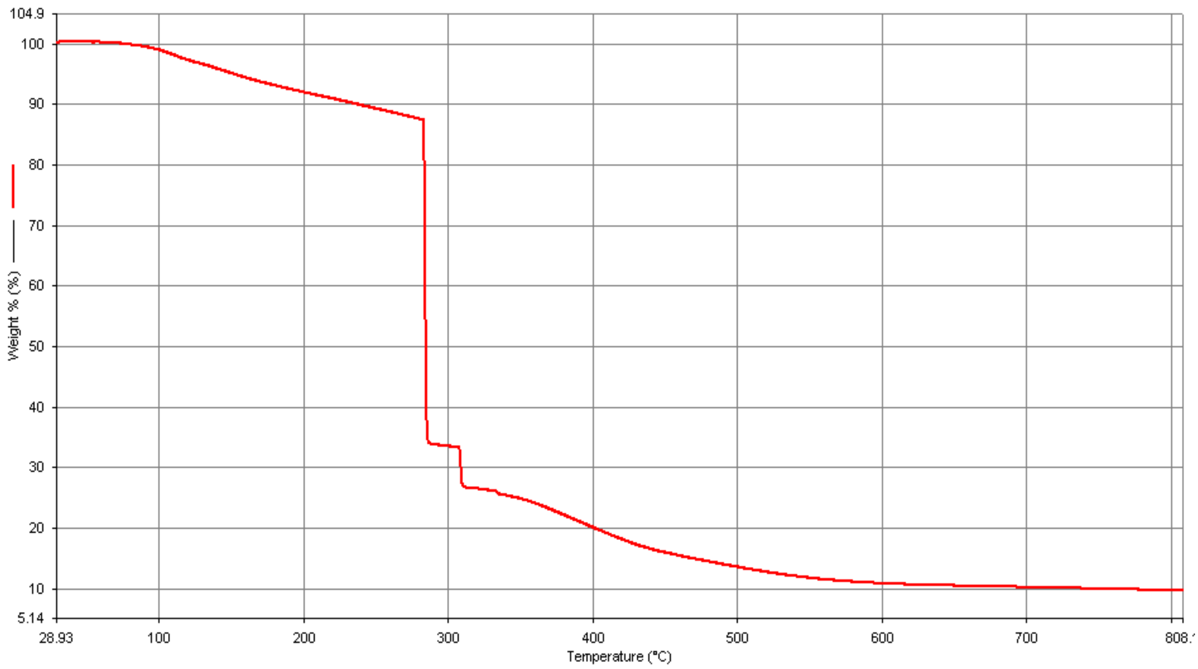
4.2.8 TGA Results for ATH and NF Substrates





Graph 5 : TGA result for ATH 5%





Graph 6 : TGA result for NF

4.3 Discussion

4.3.1 Heat Shielding Effect

The second part of the experiment consist of fire/Bunsen burning experiment. The experiment is left exposed to a burner for an hour and the end temperature is recorded every 10 minutes from the temperature gauge reader attached at the back of the steel for a good 60 minutes. This is done with the aid of ASTM E 119-00a.[16].

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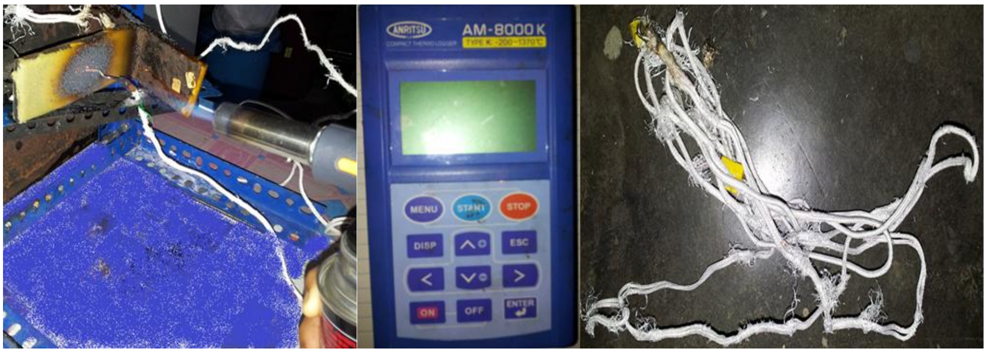

Figure 10 : Fire Test with Thermologger for Experiment use

From graphical plotted data, substrate with 5% ATH showed the best heat shielding results as per compared to no fillers recording a final back temperature .The average back temperature captured by ATH 5% is 119.05 'C where by the average tempetrature captured by NF is 147.2 'C. This results further proves that ATH 5 % has better heat shielding performance compared with the one with NF.

4.3.2 XRD Result

There were 2 samples each from 500 degree and 800 degree Celsius from both the fillers used (ATH &FS) sent for this test namely sample :

- ATH 5% (450 Degree Celsius)
- NF   (450 Degree Celsius)

From Graphical interpretation of the XRD result we observe that the ATH 5% substrates under 450 Degree Celsius contain obvious elements of :-

- Boron Oxide
- Boron Phosphate
- Graphite
- Alumina

From Graphical interpretation of the XRD result we observe that the NF substrates under 450 Degree Celsius contain obvious elements of :-

- Boron Phosphate
- Graphite
- Boron Oxide

4.3.3 TGA Result

Generally, In the range of 0-200^{o}C the weight loss is usually because of the removal of hydroxide group from polyamide hardener . In the range of 200-350^{o}C the expandable graphite oxidized by releasing CO_2 and H_2O. In the range of 350-500^{o}C the weight loss is due to the decomposition of APP to release gas of NH_3 and H_2O. In the range of 500-700^{o}C the weight loss further contributed to the releasing of phosphoric acid, poly phosphoric acid and ploy metaphosphoric acid. At 800^{o}C the weight is due to, poly metaphosphoric acid is vaporized with APP decomposing.

CHAPTER 5 : CONCLUSION & RECOMMENDATION

5.1 Conclusion

Acid source, carbon source and blowing agent are 3 main components of intumescent coating. A good sample of intumescent coating will be dependent on those 3 components. Aluminium Tri-Hydrate and NF are used in this project. ATH 5% and NF are tested in expansion of char as well as the heat shielding effects. Having completed the entire project, it is obvious that ATH filler showed the best results for both heat shielding and char expansion.

As for this project, there are three parts that are majorly concentrated..

- One, the preparation of formulation of Aluminium Tri-Hydrate samples as well as mixing grinding and coating it onto the various structural geometries.

- Secondly the applied coating for inorganic fillers (Aluminium Tri-Hydrate) are experimented with exposing it to fire using Bunsen burner and applying heat using furnace. This test is for the purpose of testing the heat shielding as well as the char expansion for both the inorganic fillers used on the various structural geometries.

- Finally, the experimented specimens are thoroughly studied with the aid of some technological equipments for better view and data collection for plotting of graph or understanding the pattern of effects and cause.

Technological visual equipments and its functions :-

Thermo gravimetric analysis - is a type of testing performed on samples that determines changes in weight in relation to change in temperature. Such analysis relies on a high degree of precision in three measurements: weight, temperature, and temperature change. As many weight loss curves look similar, the weight loss curve may require transformation before results may be interpreted. TGA is commonly employed in research and testing to determine characteristics of materials such as polymers, to determine degradation temperatures, absorbed moisture content of materials, the level of inorganic components in materials, decomposition points of explosives, and solvent residues.

X-ray scattering techniques - are a family of non-destructive analytical techniques which reveal information about the crystal structure, chemical composition, and physical properties of materials and thin films. These techniques are based on observing the scattered intensity of an X-ray beam hitting a sample as a function of incident and scattered angle, polarization, and wavelength or energy.

5.2 Recommendations

There are various angles to look at this project for room of improvement for expansion and continuation. The project can be further experimented by using different inorganic fillers that might help increase the strength of char and heat shielding effects. Improvisation on increasing the heat shielding effect so that it could be used not just onto steel products but also other metal products that degrades at different temperature.

Although steel structures are commonly used for construction of most industries in particular offshore structures, once this experimental study achieves its objective, a proper study in detail can be carried out as a new way of protecting other metal related materials that is able to withstand higher percentage of heat as well as the char expansion. Various tests can be conducted and this particular study will be very beneficial to not only the Oil and gas industries but also to other industries which can help minimize the risk and work hazard as well as increasing the safety of workplace and workers.

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